Training Simulator for Developing Laparoscopic Skills

Harrith M. Hasson, MD, Nakka V. Aruna Kumari, CSA,
Juancho Eekhout, MPP

ABSTRACT

Objective: To measure, using objective pre- and post-training assessments, the degree of improvement in laparoscopic skills following training with a new laparoscopy training simulator (LTS 2000).

Methods: This study utilized the LTS 2000 training simulator. The simulator was used in conjunction with a laparoscope joined to a camera, light source, and monitor or with a camcorder. Eleven exercises were planned with tasks designed to develop visual-motor-processing capabilities for referencing the 2-dimensional image of an object on a video screen, and to teach and allow practice of delicate manipulations, circular motions, oviductal cannulation, formation of Roeder loops, and simple suturing and knot-tying. The skill level of individual trainees was assessed before and after training with objective means. Each exercise was assigned a point value of 100 with a maximum score of 1100. Some exercises were scored in number of tasks per 1 minute, others in number of minutes per 1 task. A score of 100 was given for completing a target number of tasks in 1 minute and 0 for not completing any. A score of 100 was given for completing the assigned task in a target amount of time and 0 for not completing it in 3 times that amount. Scores between 100 and 0 were set linearly as a function of those values.

Results: Of the 11 participating physicians, none scored above the 65th percentile of the maximum achievable score before training; 8 scored above the 73rd percentile after training. The average pretest score was 304.9 points (SD 190.8) range 43.2 to 705.7; posttest score was 834.2 points (SD 141.2) range 547.3 to 1021.7. The average number of hours spent in practice was 5.9 (range 2 to 23). A positive correlation existed between hours of practice and posttest score improvement.

Conclusion: Sustained training with the new simulator resulted in significant improvement in laparoscopic skills in all tested physicians, regardless of prior level of experience.

Key Words: Laparoscopic skill development, Objective skill assessment, Laparoscopic skill training.

Department of Obstetrics and Gynecology, Louis A. Weiss Memorial Hospital (Dr Hasson, Ms Kumari).

Irving B. Harris Graduate School of Public Policy, The University of Chicago (Mr Eekhout).

Louis A. Weiss Memorial Hospital and The University of Chicago, Chicago, Illinois USA.

Address reprint request to: Harrith M. Hasson, MD, Chairman, Department of Ob/Gyn, Louis A. Weiss Memorial Hospital, 4640 N. Marine Drive, Suite 6150, Chicago, IL 60640, USA. Telephone: (773) 564-5560, Fax: (773) 564-5562, E-mail: hhasson@weisshospital.org

INTRODUCTION

Minimally invasive surgical techniques using operative laparoscopy are becoming increasingly popular. Such techniques involve remote manipulations of tissues with thin instruments directed through small incisions made into an abdomen distended with gas. The surgeon interacts with images created by a camera lens assembly and displayed on a video monitor. Surgeons accustomed to traditional techniques experience difficulty manipulating their operative instruments with reference to images on a video screen. Because video-assisted surgery is significantly different from conventional surgery, physicians skilled in the conventional approach need to acquire skills and a capacity for visual-motor processing before becoming equally proficient in laparoscopic video surgery.

The basic skill required for performing advanced laparoscopic surgery is an adequate visual-motor processing capacity for referencing the 2-dimensional image of an object projected on a video screen. Acquiring such a capacity permits the surgeon to adapt to the loss of depth perception and lack of appreciation of the temporal proximity of structures displayed on a flat plane, and to command the orientation of instruments by motions projected in the operative field.

More advanced skills call for precise control of instruments that pivot about access points remote from the surgical field; the ability to adapt to limitation of access, range of operative motions, and tissue retraction; and the capacity to execute complex manipulations requiring refined hand-eye coordination and manual dexterity. These skills may be acquired and perfected through instructions and repetitive practice on a laparoscopy training simulator.[1-3]

This report describes an improved training simulator designed to enhance laparoscopic proficiency and allow objective skill assessment and presents the results when this system was used to train 11 physicians who had various levels of prior experience.

MATERIALS AND METHODS

The laparoscopy training simulator 2000 (LTS 2000) was designed by the senior author. It is essentially a video training device that allows for simulated laparoscopic manipulations under realistic conditions. It is easily transportable and replicates the working dimensions of a distended abdomen; it is covered by a removable frame, or cassette, containing a resilient, multilayered membranous structure simulating the anterior abdominal wall. A flexible floor mat can be selectively adjusted to various heights at 3 axial positions forming various floor configurations. The floor mat is formed with Velcro strips for attachment to corresponding strips mounted on exercise platforms. The laparoscopic skill exercise models are either integral with or can be replaced and attached to the platforms. A timer/stopwatch for measuring exercise time, and posts mounted on the outside of the simulator for knot-tying practice are provided.

Models that are integrated with dedicated platforms include:

(1) The peg board-and-posts coordination model that consists of a peg board and 2 thin metallic posts, 1 with a single curve, and the other with 2 curves, permanently attached to a platform.

(2) The 3-D (dimensional)-to-2-D translation model is a platform constructed with 9 spring posts each with 3 rings, to create a virtual cube. The top 9 rings of the cube are red, the middle rings are yellow, and the bottom rings are blue.

(3) The oviduct cannulation model is composed of a malleable plastic tube, the distal end of which is shaped like the fimbriated end of an oviduct. The tube is suspended from a platform, which pivots to allow the fimbriated end to rise freely above the floor mat.

(4) The tube cannulation model is made up of a hard plastic tube joined along its entire length to a small platform. Small beads, plastic rings, and pipe cleaners are also used for the exercises with these models.

Undedicated platforms are designed to fix interchangeable models to the floor mat:

(1) The small, single-clamp platform has a 3-cm central metallic post formed with an alligator-type clamp.

(2) The drill platform contains a centrally located 9-cm sharp drill capped with a winged nut.

(3) The 4-clamp platform has 4 metallic corner posts, each formed with an alligator-type clamp.

(4) The 4-nail platform is constructed with 4 upward pointing nails.

Two preassembled models attach interchangeably to the 4-clamp or 4-nail platform:

(1) The sponge cloth model consists of a piece of cloth, with a centrally located incisional gap, which is peripherally fixed to a sponge.

(2) The blood vessel model is composed of a sponge with attached color-coded tubes bundled in close proximity to simulate artery, vein, and ureter. Other models consist of readily available items attached to 1 of the undedicated platforms. These items are generally found in grocery stores and novelty shops. A thin rubber tube may be cut into short segments; 1 segment may be fixed to the single clamp platform in a dangling position to constitute the appendix model. Another segment may be suspended between 2 single clamp platforms or 2 of the 4 clamps of the 4-clamp platform to serve as the stapling model. A medium-sized balloon filled with water may be attached to the single clamp platform to serve as the ovarian cyst-gallbladder model. An orange may be turned into the drill platform to function as the myomectomy model. A piece of meat may be cooked medium rare and fixed to the drill platform to act as the morcellator model **(Figures 1 and 2)**.

The simulator is used with a standard laparoscope attached to a video camera, light source, and video monitor placed at a comfortable height for viewing. The laparoscope is introduced through a primary cannula inserted through the simulated abdominal wall.

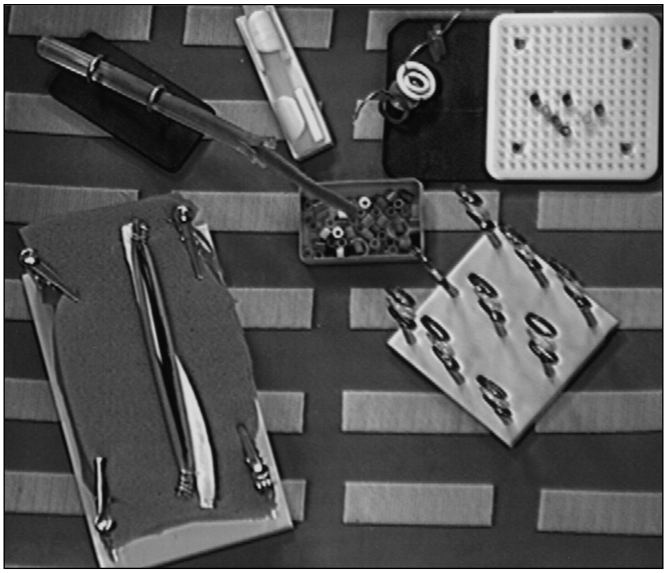

Figure 1. Internal view of the laparoscopy training simulator 2000 (LTS 2000) showing the floor mat with Velcro strips and attached exercise models. Shown counter clockwise are the pegboard-and-post, straight tube, oviduct cannulation, blood vessel and virtual cube models. A small box with beads and rings is seen next to the pegboard-and-post model.

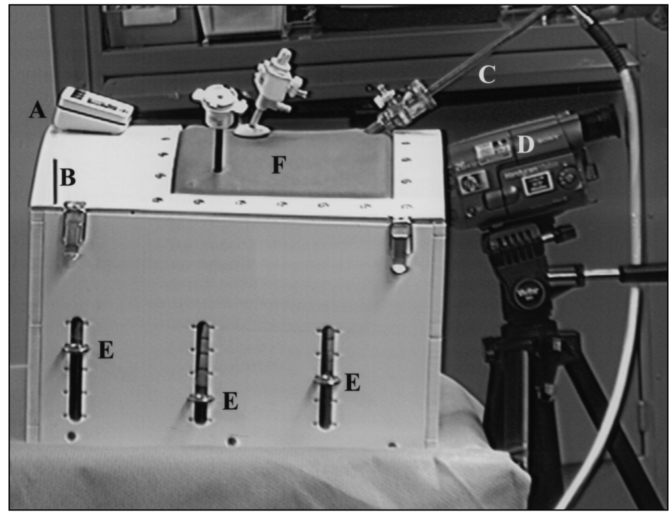

Figure 3. External view of the laparoscopy training simulator 2000 (LTS 2000). (A) Timer for measuring exercise time. (B) External post for practicing knot tying. (C) Laparoscope with attached light source and camera (not shown). (D) Camcorder mounted on a standard tripod: an alternative camera-lens assembly. (E) Control rings for adjusting the height of the flexible floor mat. (F) Removable frame containing resilient structure simulating the anterior abdominal wall.

Figure 2. Internal view of the LTS 2000 showing other exercises: balloon cyst inside a zip lock bag, sponge-cloth suturing model, meat morcellation and balloon cyst models.

Alternatively, the camera lens assembly may be furnished by a camcorder mounted on a standard tripod to supply a stable and magnified view of any portion of the box's interior when connected to a video monitor. The laparoscopic video camera or camcorder may be connected to a standard video recorder to permit subsequent review and analysis of the exercise manipulations **(Figure 3)**.

Training with the LTS 2000 simulator is conducted in the following manner. The simulator box is placed on a table with the top of the box at the level of the operator's wrists. The 2 metal posts are inserted into corresponding openings on the exterior wall of the simulator. The abdominal wall frame is removed to expose the interior surface of the box. The control rings are used to adjust the floor mat to a desired configuration. Exercise models are attached to the floor mat, and the abdominal wall frame is returned to its original locked position.

The first trocar is inserted through the rubbery abdominal wall in the midline, approximately 3 cm from 1 edge of the frame. Three secondary trocars are inserted into the simulator closer to the contralateral frame edge. Once inserted, the cannulas remain stable on the abdominal wall and do not need to be changed or replaced. The laparoscope, with attached camera and light source, is introduced into the simulator through the primary port and exercise manipulations are initiated. Practice with the laparoscope requires 2 individuals; an assistant manipulates the scope, and the operator uses 2 hands to perform the exercise. No assistant is needed when the camcorder is used.

In this study, all pre- and posttests were conducted with the laparoscope; the camcorder was used for practice only. Following conclusion of the pretest, detailed instructions were given and each exercise was practiced initially under supervision. The training exercises used for testing with the LTS 2000 are summarized in **Table 1**. Exercises not included in the testing program but used for practice purposes are summarized in **Table 2**.

The testing was conducted in the following manner. For exercises 1 through 6, the instructor (NAK) recorded the number of successful exercise tasks completed in 1 minute. The timer was reset for 1 minute after each exercise. Exercises 7 through 11 had no time limit. The instructor recorded the time taken to accomplish 1 successful task and then reset the timer for the following exercise. The name of the trainee, status (resident or attending physician), and date of the test were entered on the pre- and posttest forms. A log was kept to detail the amount of time each trainee accumulated with the simulator.

The mathematical basis of the scoring system was developed by one of the authors (JE). The scoring was conducted in the following manner. Each exercise was given an equal rank and assigned a point value of 100, giving the test a maximum score of 1100 points. Exercises 1 through 6 were scored on the basis of the number of tasks completed in 1 minute, for instance, the number of beads placed on the peg board. A standard number of tasks were set prior to the training, based on the performance of two of the authors (HMH, NAK). A score of 100 was given to those trainees who equaled or exceeded the preestablished number of tasks. Some of the trainees were able to complete a higher number of tasks after being trained. For example, making 3 Roeder loop ties on the external post in 1 minute was preestablished by the authors as the desirable end point of the first exercise. Subsequently, some of the trainees were able to set down 4 ties in 1 minute. Therefore, instead of evaluating the other scores on the basis of the initial target of 3, a new target value of 3.5 was set. The best score (100) was given to trainees who completed 3 or 4 tasks in 1 minute in Exercise 1 and the worst score (0) was given to those who could not complete a single task. Scores between the maximum and the minimum were set linearly as a function of those values. The equation for such a line was calculated on the basis of the upper limit (100, target value) and the bottom limit (0, no tasks completed). For Exercise 1, for example, the upper limit in the calculation of the slope (Y2-Y1)/(X2-X1) was 3.5 instead of 3 or 4, ie, (100-0)/(3.5-0).

For Exercises 7 to 11, the best score (100) was established on the basis of the best performance (shortest time to accomplish task). The worst score (0) was allocated to trainees who did not complete the task within a period of time 3 times greater than the best time. For example, in Exercise 7, trainees who cannulated the simulated oviduct using a pipe cleaner in the best time of 0.8 minutes were given a score of 100. Those who failed to cannulate the oviduct in 2.4 minutes were given a score of 0. Trainees who completed the exercise task in an intermediate period of time, between the best and the maximum allowed, received scores that were calculated linearly as a function of these 2 values **(Table 3)**.

For methodological reasons, the authors modeled 2 other types of scoring systems, one based on a pure linear relationship between the best (100) and the worst score (0), and the other based on a random distribution (bell curve), where each trainee was graded as compared with his or her colleagues' performance on each exercise. All 3 scoring systems led to very similar conclusions. The method selected was thought to be most applicable.

RESULTS

Between January 1999 and March 2000, 11 physicians utilized the LTS 2000 simulator, completed a pretest, received instructions to enhance their laparoscopic skills, and then completed a posttest after 2 to 23 hours of practice. All 11 physicians experienced significant improvement in the test scores in coordination, manipulation, suturing, and knot tying, as shown in **Tables 4 and 5**. Fifteen other physicians were trained on the simulator but did not complete the posttest and were excluded from the study.

The average pretest score was 304.9 points (SD 190.8), with a range of 43.2 to 705.7. The average posttest score

Table 1.
Training Exercises Used for Testing with the LTS-2000.

Ex.*	Models	Activity	Skill Taught	Instruments	Supplies
1	External Post	Form Roeder loop knot over external post	Tying an EC† knot	0	String
		Models Integrated with Platforms			
2	Pegboard-and–post coordination	Pick up beads from cup; place beads on peg board using a fine alligator held in dominant hand	Orientation, hand-eye coordination between dominant and non-dominant hands, manual dexterity; fine manipulations of 3-D objects from 2-D screen	Alligator‡	Beads
3	Same	Use non-dominant hand to pick up and transfer beads to dominant hand for placement on pegboard		2 Alligators	Beads
4	Same	Pick up plastic rings with dominant hand; feed onto post with one curve		Alligator	Rings
5	Same	Pick up plastic rings; feed onto post with two curves	Also circular motion	Alligator	Rings
6	3D-to-2D translation	Pass long probe between rings at 3 levels, guided by color code	Overcome problems of depth perception	Long probe	0
7	Oviduct cannulation	Elevate fimbriated end of plastic tube with non-dominant hand; feed pipe cleaner through it with dominant hand	Cannulation of simulated oviduct	2 Alligators	Pipe cleaner
		Models Replaceably Attached to Platforms			
8	Rubber tube appendix	Fix model into single clamp platform in dangling position; form Roeder loop on external post; bring loop into box with alligator; pull tube into loop; cinch loop with knot pusher. Repeat process. Cut tube between two loop ties.	Loop knot-tying to isolate a tubal structure	Alligator Knot-pusher Scissors	Free suture
9	Blood vessel	Fix model into 4-clamp or 4-nail platform; pass needle behind vessel(s), excluding ureter; tie suture with extracorporeal knot and knot pusher	Hemostatic tying of blood vessel	Needle holder, 2 Alligators, Knot-pusher, Scissors	Suture on needle
10	Sponge cloth suturing	Fix model to 4-clamp or 4-nail platform; take single stitch to approximate edges of simulated incision; tie with EC** knot and knot pusher	Stitching and tying with EC* knot		
11	None	Add two half hitches to exercise 9 or 10	Intracorporeal knot tying	2 Alligators	0

*Ex. = Exercise, †EC = Extracorporeal, ‡Alligator = Laparoscopic Alligator Forceps.

Table 2.
Training Exercises Not Used for Testing with the LTS-2000.

Ex.	Models	Activity	Skill Taught	Instruments	Supplies
		Models Integrated with Platforms			
12	Tube cannulation	Feed pipe cleaner through hard tube and withdraw from the other side with non-dominant hand	Cannulation, coordination between dominant and non-dominant hand	2 Alligators	Pipe cleaner
		Models Replaceably Attached to Platforms			
13	Rubber tube stapling	Suspend tube between 2 clamps of the 4-clamp platform, apply staples over tube twice, cut tube between staples	Stapling of tubular structures	Stapling device, Scissors	Staples
14	Sponge cloth suturing	Fix model into 4-clamps or 4-nail platform, place single stitches and tie with intracorporeal knot	Intracorporeal knot-tying	Needle holder, 2 Alligators, Scissors	Suture on needle
15	Same	Fix model into 4-clamps or 4-nail platform, place a continuous suture consisting of 3 or more passages. Secure the suture line with beginning and end knots	Continuous suturing and knot tying at the beginning and end of suture line	Needle holder, 2 Alligators, Scissors	Suture on needle
16	Orange myomectomy	Fix orange into drill platform. Make elliptical incision to expose pulp; separate skin from pulp with tunneling and prying	Sharp and blunt dissection	Knife, scissors, probe, toothed forceps	Orange
17	Meat morcellation	Fix a piece of cooked meat into drill platform; morcellate using knife and mechanical morcellator	Morcellation	Knife, toothed foceps, Mechanical Morcellator	Cooked Meat
18	Balloon cyst	Attach a balloon filled with water to single clamp platform. Introduce zip lock bag into box, open bag, drop balloon into bag, close bag, draw up to port site	Extraction of cyst using bag	3 Alligators	Balloon, Zip-lock bag

*Ex. = Exercise.

was 834.2 points (SD 141.2), with a range of 547.3 to 1021.7. When the pre- and posttraining scores were compared, the average increase in the posttest score was 529.3 points (SD 200.2), with a range of 280.3 to 934.7 points. The average number of hours spent in training was 5.9 with a range of 2 to 23.

A wide variation occurred in the pretest scores of participating physicians. This is not surprising because participating residents came from 3 programs in the city with different emphases on laparoscopic training, and one of the physicians had no previous experience with operative laparoscopy, but the other was an experienced laparoscopist. Furthermore, individual variations in inherent abilities of the trainees played a role in explaining their performance on the pretest. However, after training with the LTS 2000, the variations on the posttest

Table 3.
Skill Scoring System.

A-Exercises scored in number of tasks per one minute

EXERCISE 1:		EXERCISE 2:		EXERCISE 3:		EXERCISE 4		EXERCISE 5:		EXERCISE 6:	
Tasks*	Score	Tasks*	Score	Tasks*	Score	Tasks*	Score	Tasks*	Score	Tasks*	Score
0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1	28.6	1	18.2	1	28.6	1	20.0	1	28.6	1	18.2
2	57.1	2	36.4	2	57.1	2	40.0	2	57.1	2	36.4
3	85.7	3	54.5	3	85.7	3	60.0	3	#N/A	3	54.5
4	100.0	4	72.7	4	100.0	4	80.0	4	100.0	4	72.7
		5	90.9			5	100.0			5	90.9
		6	100.0			6	100.0			6	100.0
100 Target Values											
	3.5		5.5		3.5		5.0		4.0		5.5

B-Exercises scored in number of minutes per one task

EXERCISE 7:		EXERCISE 8:		EXERCISE 9:		EXERCISE 9:		EXERCISE 10:		EXERCISE 11:	
Min**	Score	Min**	Score	Min**	Score	Min**	Score	Min**	Score	Min**	Score
0.8	100.0	1.8	100.0	2.7	100.0	9.0	0.0	4.0	100.0	1.0	100.0
1.0	87.5	2.0	94.4	3.0	94.4	10.0	0.0	4.3	95.8	1.4	79.2
1.3	66.7	2.8	71.3	3.3	88.3	11.3	0.0	5.0	87.5	1.5	75.0
1.4	61.5	3.0	66.7	3.8	79.0			6.0	75.0	1.9	54.2
1.8	40.6	4.0	38.9	4.0	75.9			7.0	62.5	2.0	50.0
2.0	25.0	5.0	11.1	4.6	65.1			8.0	50.0	3.0	0.0
2.8	0.0	6.0	0.0	5.0	57.4			10.0	25.0	3.3	0.0
3.0	0.0	7.0	0.0	6.0	38.9			11.9	1.0	4.0	0.0
4.6	0.0	10.0	0.0	6.6	28.7			12.0	0.0	25.0	0.0
8.0	0.0	10.3	0.0	7.0	20.4			15.0	0.0		
8.3	0.0	10.6	0.0	8.0	1.8			16.0	0.0		
Zero Target Times											
2.4		5.4		8.1				12.0		3.0	

* Number of tasks completed in one minute ** Number of minutes to complete one task.

Table 4.
Pre vs. Post Training Scores of 11 Trainees.

A-Exercise scored in number of tasks per minute

	EXERCISE 1:		EXERCISE 2:		EXERCISE 3:		EXERCISE 4		EXERCISE 5:		EXERCISE 6:	
	Pre 1	Post 1	Pre 2	Post 2	Pre 3	Post 3	Pre 4	Post 4	Pre 5	Post 5	Pre 6	Post 6
AL	0	4	0	4	0	2	0	3	0	1	1	5
CR	0	3	1	5	0	3	1	4	0	4	1	5
JO	1	4	1	6	1	2	2	3	0	1	2	2
RD'A	0	3	0	4	1	2	0	2	0	2	2	4
SDR	1	3	2	3	1	0	2	2	1	0	2	4
KC	2	3	2	4	1	2	0	2	0	2	2	5
AMCE	1	3	1	4	1	3	3	5	2	4	3	4
MK	2	4	2	5	2	3	1	3	0	2	2	3
LR	2	3	1	4	2	2	2	5	1	2	5	6
GFP	2	3	3	4	1	4	3	3	2	4	0	5
RS	2	3	3	5	2	3	3	6	2	4	2	6

B-Exercises scored in number of minutes per task

	EXERCISE 7:		EXERCISE 8:		EXERCISE 9:		EXERCISE 10		EXERCISE 11:	
	Pre 7	Post 7	Pre 8	Post 8	Pre 8	Post 9	Pre 10	Post 10	Pre 11	Post 11
AL	8.0	1.3	10.0	1.8	9.0	3.8	10.0	6.0	3.0	1.4
CR	3.0	1.0	10.3	2.0	10.0	4.0	12.0	4.0	4.0	1.0
JO	8.3	1.8	5.0	4.0	8.0	3.0	10.0	5.0	3.0	1.0
RD'A	1.0	1.0	6.0	2.0	6.0	4.0	10.0	5.0	3.0	1.0
SDR	3.0	2.0	3.0	3.0	8.0	4.6	15.0	5.0	3.3	2.0
KC	3.0	1.0	7.0	3.0	8.0	4.0	6.0	4.0	1.9	1.0
AMCE	2.8	1.4	2.8	2.8	6.6	4.0	16.0	4.3	25.0	1.0
MK	2.8	1.3	10.0	2.0	5.0	3.3	10.0	6.0	1.5	1.0
LR	4.6	2.0	10.6	5.0	11.3	7.0	11.9	5.0	1.5	2.0
GFP	1.0	1.0	5.0	3.0	6.0	4.0	7.0	4.0	2.0	1.0
RS	0.8	0.8	2.0	2.8	6.0	2.7	8.0	5.0	1.0	1.0

E = Exercise; Pre = Pretest number of tasks completed in one minute for exercises 1-6 and number of minutes to complete one task for exercises 7-11; Post = Posttest values.

Table 5.
Effect of Simulator Training on Skill Scores.

Trainee	Status*	Pretest Score	Pretest Percentile†	Posttest Score	Posttest Percentile‡	Practice Hours	Point Improvement
AL	1 YR	43.2	3.93%	808.2	73.48%	6.0	765.1
CR	ATT1	56.4	5.12%	991.1	90.10%	23.0	934.7
JO	2 YR	189.6	17.24%	743.5	67.59%	4.0	553.9
RD'A	3 YR	216.3	19.67%	830.8	75.53%	2.0	614.5
LR	3 YR	266.9	24.27%	547.3	49.75%	3.0	280.3
SDR	4 YR	289.4	26.31%	833.7	75.79%	2.0	544.3
KC	4 YR	347.0	31.55%	921.4	83.76%	3.0	574.4
MK	3 YR	364.4	33.13%	872.7	79.33%	3.3	508.3
AMCE	4 YR	368.0	33.45%	666.7	60.61%	6.0	298.7
GFP	3 YR	507.4	46.13%	939.4	85.40%	7.0	432.0
RS	ATT2	705.7	64.15%	1021.7	92.88%	6.0	316.1
Averages		304.9		834.2		5.9	529.3
Std deviation		190.8		141.2			200.2

*Status ranked by level of pretest score. 1-4 yr. = first to fourth year resident. Att = attending. Att1 = no previous experience in advanced laparoscopic surgery. Att2 = substantial experience in laparoscopic surgery.
†Percentile of the maximum achievable score.

scores were not influenced much by the level of the pretest score. This finding indicates that the number of hours invested in the training was the primary reason for the noted improvement in the posttest score, as the inherent abilities of each trainee remains constant. Improvement in the posttest scores correlated with the number of hours invested in training (P = 0.055). The greatest improvement was noted in physicians who had the lowest pretest score.

When the benchmark for skill testing was set at the 70th percentile of the maximum achievable score, none of the physicians passed the test prior to training. Eight of the 11 physicians scored higher than 73% after training and practice **(Table 5)**. The difference between pre- and posttest scores of individual exercises is shown in **Table 6**. The mean pretest scores for all exercises was 27.7 out of 100 and for posttest scores was 75.8 out of 100.

DISCUSSION

The need for frequent preparation and training is not unique to laparoscopic surgeons; it is shared by all performers with highly developed skills including professional musicians and athletes, as previously noted by Resnick.[2] The technical expertise of a laparoscopic surgeon will ultimately depend on inherent genetic abilities, modulated by acquired knowledge and experience, and improved by practice.

Rosser et al[3,4] pioneered the use of objective parameters to evaluate laparoscopic skills in 2 studies of a first-generation laparoscopy trainer. The authors first trained attending surgeons using dexterity and intracorporeal suturing drills. The dexterity exercises consisted of (1) the rope pass drill, grasping a rope with color coded bands and successively passing it from 1 hand to the other; (2) the cup drop drill, dropping a pea into an aperture of an inverted cup using the nondominant hand; (3) the triangle transfer drill, transferring a triangular wooden block from 1 area to another by engaging and disengaging a curved needle into and from a plastic loop at the apex of the triangle. The authors found that the time needed to perform the dexterity drills improved among participants with successive drills resulting in a significant difference ($P < .001$) between the time required for the first and tenth drill. Similarly, significant improvement ($P < .001$) was noted in performing intracorporeal suturing with successive drills, after the participants received instruction. A significant correlation ($P < .001$) was also observed between the performance efficiency of the dexterity and suturing drills, suggesting that dexterity drills help improve suturing. To evaluate the results, the authors correlated the mean time required to perform a drill with that of participants who completed all 10 drills and 10 suturing exercises.[3] In the second study, these authors compared the performance of senior surgeons with that of residents after both groups had completed the training program the authors previously designed. The collective performance of the residents was similar to that of the trained surgeons in the rope pass drill and suturing exercises. However, the residents performed the triangle transfer drill faster and the cup drill more slowly than the trained surgeons.[4]

Using objective parameters, Derossis et al[5] also used a first-generation laparoscopy trainer to train attending and resident surgeons with various degrees of experience. Their scoring system rewarded accuracy and speed. The simulated laparoscopic tasks consisted of (1) peg transfers, lifting a peg from 1 peg hole with 1 hand, transferring it to the other hand and placing it on another peg board; (2) pattern cutting, cutting a circular pattern out of a larger piece of gauze; (3) clip and divide, placing 2 hemostatic clips on a tubular foam structure and cutting in between; (4) endo-looping, placing a pretied slip knot on a foam tubular appendage; (5) mesh application, placing a mesh over a defect in a foam model and securing it to the foam with staples; (6) intracorporeal knot, placing a suture into a Penrose drain and tying it with an intracorporeal knot; (7) extracorporeal knot, placing a suture into a Penrose drain and tying it with an extracorporeal knot. Timing and penalty scores were assigned to each exercise. All 7 tasks showed a significant improvement in performance with repetition ($P < 0.0001$). Some of the tasks (1, 2, 6) showed a significant correlation between the degree of physician experience and score, but others did not.[5] When the Canadian group further studied the effect of practice on performance, they found that residents who had a pretest followed by 5 weekly practice sessions showed significant improvement in the posttest score for each task and for total score.[6] Residents who limited their practice to the pretest showed improvement in tasks 1, 4, 5, and 7, but not in 2, 3, and 6 in the posttest. The total score of the posttest was not statistically different from that of the pretest in this group.[6]

Table 6.
Difference Between Pre and Posttest Scores by Individual Exercise.

	Average Pretest Score	Average Posttest Score
Exercise 1	33.77	89.61
Exercise 2	26.45	78.51
Exercise 3	31.17	66.23
Exercise 4	30.91	67.27
Exercise 5	20.78	62.33
Exercise 6	36.36	79.34
Exercise 7	25.00	66.86
Exercise 8	23.14	70.45
Exercise 9	18.93	75.22
Exercise 10	26.23	89.39
Exercise 11	32.20	89.02
Mean	27.7	75.8

We used a new second-generation laparoscopy trainer, a complementary set of dexterity and suturing exercises, and a scoring system that is different from that described by the previous authors. The Eekhout formula gives a precise score for any skill exercise based on the number of tasks completed in a unit of time or the number of minutes needed to complete a given task. A maximum score of 100 is given for achieving a target value or time; a minimum score of 0 is given for not completing a single task in the unit of time or the assigned task in 3 times the target time. Scores between 100 and 0 are set linearly as a function of those values. A user-friendly software computer program containing the algorithm has been developed for the benefit of future investigators. To calculate the skill scores of trainees for any given exercise with a known target value or time, the investigator simply needs to plug in the number of tasks the trainee completed per unit of time, or the number of minutes needed to complete a task. The program will then compute and tabulate the information presented in **Tables 3-6**, as required.

Physicians who are adept at performing conventional surgery possess the knowledge of surgical principles and the skills of operative manipulation. To become proficient in laparoscopic surgery, they need to master only the necessary adaptations in visual-motor processing through training and practice. Physicians who do not perform advanced laparoscopic surgery on a regular basis have a particular need for ongoing simulator training to maintain a reasonable level of competence. The present study suggests that most physicians acquire competence in skill sets associated with advanced operative laparoscopy if they receive appropriate instructions and invest a reasonable amount of time practicing on a laparoscopy training simulator like the LTS 2000.

Expert laparoscopists can also benefit from utilizing the LTS 2000 simulator for trying out new instruments and methods before using them in the operating room, and for practicing newly acquired skills. Our group has been able to resolve many of the problematic subtleties associated with novel applications by testing them in the simulator before performing live surgery.

CONCLUSION

The ultimate goal of any laparoscopy training system is to increase the comfort level and efficiency of laparoscopic surgeons in the operating room. The 11 physicians who participated in this training system experienced significant improvement in their laparoscopic skills regardless of prior level of expertise: all 11 scored below the 65th percentile of the maximum achievable score prior to training and 8 scored above the 73rd percentile after training and practice. The improvement in the posttest scores correlated with the number of hours invested in training ($P = 0.055$). A larger trial is needed to validate these preliminary results.

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Disclosure Statement: The senior author holds patents on the training simulator and would collect royalties on sales.